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Original article

Osteological study of lumbar vertebrae in Western Maharashtra population

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KEYWORDS

Lumbar vertebrae, Lumbar stenosis, Canal body ratio, Spinal index of Jones.

ABSTRACT

Introduction: Anatomical studies have been conducted in different ethnic groups to measure the bony vertebral dimensions and to determine the normal limits which will serve as guidelines in assessing lumbar stenosis. *Aim*: To determine the normal range of measurements of lumbar vertebrae in Western Maharashtra population. *Materials and methods*: Various dimensions of lumbar vertebrae from L_1 to L_5 were measured in 420 lumbar vertebrae, collected from the Department of Anatomy, Government Medical College, Miraj, and other Medical colleges of Western Maharashtra. *Results and discussion*: Mean transverse diameter of vertebral body as well as of spinal canal and anteroposterior diameter of vertebral body were minimum at L_1 and maximum at L_5. The mean anteroposterior diameter of spinal canal showed a gradual decrease from L_1 to L_5 in both sexes. Making use of the above parameters, the canal body ratio and spinal index of Jones were calculated. These parameters were also compared with those of previous studies. Similarly, from the above parameters, the values suggestive of lumbar canal stenosis and intraspinal tumor were calculated. *Conclusion*: The present study shows regional and ethnic variation in the parameters of lumbar vertebrae, thus emphasizing the need to determine the normal range of values for different populations.

1. Introduction

The vertebral column forms the central axis comparable to a pillar, forming the main support for the bones and muscles. It is specially adapted to protect the spinal cord, support the weight of the body, and transmit the same to the ground through the pelvic girdle and inferior extremities. The lumbar part of vertebral canal houses the conus medullaris and the cauda equina. The bony wall of the canal is unyielding and therefore an abnormal spinal canal stenosis at this level may lead to compression of the nerve roots. This produces a wide spectrum of symptoms, ranging from low backache to neurological manifestations.[1–7]

There can either be narrowing or enlargement of spinal canal because of some pathological process. The narrowing can be either congenital or acquired. Conditions such as intraspinal tumor lead to enlargement of spinal canal. Enlargement of vertebral body may occur due to nonweight-bearing conditions (paralysis, fibrous dysplasia) or there can be congenital enlargement.[8] Hence, it is important to know the normal range of various dimensions of vertebrae. Thus, the present study has been conducted to measure the bony vertebral dimensions, to aim at determining the normal limits which will serve as guidelines in assessing stenosis, and to find out if there are regional and sexual differences in the lumbar vertebral dimensions.

2. Materials and methods

Four hundred and twenty lumbar vertebrae (eighty-four complete sets of lumbar spine) aged between twenty-five years and fifty years of known sex (forty-four sets of male and forty sets of female), collected from the Department of Anatomy, Government Medical College, Miraj, and other

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Medical colleges of Western Maharashtra were used for the study. Medical histories were not available for the subjects but it was ensured to the possible extent that material from persons who died of chronic skeletal disorders or related causes were not included. Care was also taken to exclude specimens showing osteophytes or other evidence of bone disease. Only those specimens which appeared normal were studied.

Various measurements were taken by using a Vernier caliper and were recorded to the nearest tenth of a millimeter. Following measurements were taken at each vertebral level:

1. The transverse diameter of spinal canal: This was taken as the minimum distance between the medial surfaces of the roots of the vertebral arch of a given vertebra (Fig. 1).
2. The transverse diameter of vertebral body: This was measured as the minimum transverse distance across the vertebral body, which is at the mid vertebral level (Fig. 2).
3. The anteroposterior diameter of spinal canal: This was taken as the distance between the posterior margin of the body and the midpoint of the vertebral arch (Fig. 3).
4. The anteroposterior diameter of vertebral body: It was measured at mid waist level of the vertebral body (Fig. 4).

The following indices were obtained from the above measurements, using the methods described by respective workers:

1. The 'canal body ratio' (C/B)[9]: This was calculated by considering transverse diameters of vertebral body and corresponding spinal canal as follows:
   C/B = transverse diameter of spinal canal/transverse diameter of vertebral body
2. The spinal index of Jones[10]: This is a ratio of spinal canal and vertebral body dimensions and was described by Jones RAC and Thomson JLG in 1968. It was obtained by using the following formula:
   $I = C_{AP} \times C_{TRANS}/B_{AP} \times B_{TRANS}$

where I represents the spinal index of Jones, C_{AP} the anteroposterior diameter of spinal canal, C_{TRANS} the transverse diameter of spinal canal, B_{AP} the anteroposterior diameter of vertebral body, and B_{TRANS} the transverse diameter of vertebral body. The range, mean, and standard deviation of the measurements of adult lumbar vertebrae were calculated. For better accuracy, the maximum and minimum limits were calculated by adding or subtracting standard deviation to or from the mean value of each measurement, respectively.[11] This gives the calculated range. Carefully measured individual values of the dimensions falling outside the given limits should thus be viewed with suspicion of abnormality. To know whether the difference was statistically significant between the means of parameters studied for male and female vertebrae, the 'P' value was calculated by applying the 'Z' test. The observations are presented in the form of tables.

3. Results

Four hundred and twenty lumbar vertebrae were studied. The results of transverse and anteroposterior diameter of lumbar spinal canal and vertebral body from L1 to L5 are shown in Tables 1 and 2, while the calculated indices, canal-body ratio, and the spinal index of Jones are presented in Tables 1 and 3. Table 4 shows the values indicating spinal stenosis and intraspinal tumor at each vertebral level. The comparison of transverse diameter of spinal canal, vertebral body, and canal body ratio with previous study is shown in Table 5, while Table 6 shows the comparison of mean transverse diameter of spinal canal and vertebral body in males and females of present study with that of previous studies. Table 7 shows the comparison of mean anteroposterior diameter of spinal canal and vertebral body in males and females of present study with that of previous studies.

4. Discussion

The clinical value of spinal canal measurements is twofold. First, expanding intraspinal masses which enlarge the spinal

Table 1 – The transverse diameter of spinal canal and vertebral body with corresponding calculated canal body ratio.

Level	Sex	Transverse diameter of spinal canal				Transverse diameter of vertebral body				Canal body ratio
		Mean	Range	S.D.	P value	Mean	Range	S.D.	P value	
L_1	M	22.16	16–25	2.38	<0.001	36.19	32–42	2.31	<0.001	0.61
	F	19.84	14–24	2.49		33.34	28–38	2.63		0.59
L_2	M	22.66	18–25	2.21	<0.001	38.09	33–43	2.47	<0.001	0.60
	F	20.16	14–24	2.44		35.22	28–40	2.85		0.57
L_3	M	23.66	20–27	1.88	<0.001	40.19	35–44	2.26	<0.001	0.59
	F	21.59	15–25	2.21		37.16	31–43	2.91		0.58
L_4	M	24.78	20–29	2.24	<0.01	42.44	37–47	2.47	<0.001	0.59
	F	23.09	17–26	2.08		39.69	33–45	2.87		0.58
L_5	M	27.03	21–32	2.76	<0.05	45.44	41–50	2.82	<0.001	0.60
	F	25.47	20–29	2.24		41.64	35–48	3.03		0.61

S.D.: Standard deviation; P: Probability or the level of significance for difference between the two means.

Table 2 – The anteroposterior diameter of spinal canal and vertebral body.

Level	Sex	Anteroposterior diameter of spinal canal				Anterposterior diameter of vertebral body			
		Mean	Range	S.D.	P value	Mean	Range	S.D.	P value
L_1	M	16.63	13–20	1.56	<0.05	29.50	26–34	2.17	<0.001
	F	15.66	13–21	1.72		27.03	22–31	2.28	
L_2	M	15.66	12–19	1.84	N.S.	30.34	26–34	2.19	<0.001
	F	15.00	12–20	1.76		27.88	22–32	2.59	
L_3	M	15.03	11–18	1.79	N.S.	31.09	28–35	2.08	<0.001
	F	14.31	11–18	1.65		28.47	22–32	2.69	
L_4	M	14.50	10–17	1.87	<0.05	31.75	28–38	2.36	<0.001
	F	13.50	10–17	1.67		29.09	23–33	2.77	
L_5	M	13.84	10–16	1.78	<0.05	32.28	28–40	2.41	<0.001
	F	12.78	10–16	1.70		29.84	23–35	3.13	

S.D.: Standard deviation; P: Probability or the level of significance for difference between the two means; N.S.: Nonsignificant difference.

Table 3 –The spinal index of Jones.

Level	Sex	Spinal index of Jones		
		Mean	S.D.	P value
L_1	M	1:2.97	0.58	<0.05
	F	1:2.71	0.44	
L_2	M	1:3.37	0.60	<0.05
	F	1:3.10	0.49	
L_3	M	1:3.56	0.62	<0.05
	F	1:3.27	0.54	
L_4	M	1:3.64	0.62	<0.05
	F	1:3.35	0.56	
L_5	M	1:3.89	0.64	<0.01
	F	1:3.42	0.61	

S.D.: Standard deviation; P: Probability or the level of significance for difference between the two means.

canal can be detected. Second, bony encroachment upon the spinal canal can be diagnosed.[12]

The first recognizable example of lumbar stenosis was provided by the Greek God Hephaestus, who was having Achondroplasia, limped as the result of trauma to an already narrowed spinal canal.[13,14] Narrowing of the spinal canal may be developmental, or it may be the consequence of degenerative changes from ageing, injury or disease, or of spinal operations. Recognition of the two types of stenoses thus depends, in part, on the proof of involvement of transverse and sagittal diameter which necessitates their baseline values for diagnostic use. Recently, it has been pointed out that instead of measuring the vertebral canal for evaluating the degree of stenosis, it would be more reliable if the ratio of the vertebral canal and of the vertebral body i.e., canal body ratio (C/B) is taken as index for calculating the degree of stenosis.[9] Thus, the present study aims at determining the normal standards for the dimensions of lumbar spinal canal on dry vertebrae. When the mean values of different dimensions of the vertebrae were compared, it showed a significant difference in males and females at all lumbar levels.

4.1 *Transverse diameter of spinal canal*

The transverse diameter was minimum at L_1 and maximum at L_5. Such an increasing trend was seen in both the sexes;

Table 4 – Values indicating spinal stenosis and intraspinal tumor at each vertebral level.

Level	Sex	Transverse diameter of spinal canal		Anteroposterior diameter of spinal canal		Spinal index of Jones	
		Spinal stenosis	Intraspinal tumor	Spinal stenosis	Intraspinal tumor	Spinal stenosis	Intraspinal tumor
L_1	M	<15.00	>29.31	<11.94	>25.43	>1:4.71	<1:1.23
	F	<12.37	>27.41	<10.51	>24.02	>1:4.03	<1:1.39
L_2	M	<16.03	>29.28	<10.13	>24.82	>1:5.17	<1:1.57
	F	<12.84	>27.50	<9.72	>23.04	>1:4.57	<1:1.63
L_3	M	<18.03	>29.29	<9.67	>23.99	>1:5.42	<1:1.70
	F	<14.96	>28.23	<9.35	>21.64	>1:4.89	<1:1.65
L_4	M	<18.06	>31.50	<8.90	>22.42	>1:5.50	<1:1.78
	F	<16.84	>29.35	<8.50	>20.28	>1:5.03	<1:1.67
L_5	M	<18.74	>35.35	<8.50	>20.45	>1:5.81	<1:1.97
	F	<18.74	>32.20	<7.68	>18.90	>1:5.25	<1:1.59

Table 5 – Comparison of transverse diameter of spinal canal, vertebral body, and canal body ratio with previous study.

Dimensions	Level	Authors	
		Present study	Devi[7]
Transverse diameter of spinal canal	L_1	21	19.6
	L_2	21.41	19.76
	L_3	22.63	20.36
	L_4	23.94	22.38
	L_5	26.25	24.62
Transverse diameter of vertebral body	L_1	34.77	37.85
	L_2	36.66	40.29
	L_3	38.67	42.09
	L_4	41.06	47.62
	L_5	43.64	46.33
Canal body ratio	L_1	0.60	0.52
	L_2	0.58	0.49
	L_3	0.59	0.48
	L_4	0.58	0.49
	L_5	0.60	0.53

however, the mean values were lower in females than in males. This difference in males and females was statistically highly significant. The female lumbar canal shows smaller measurements which are attributable, perhaps, to the greater differences in general somatic size, as compared to males. Considering the calculated range, values less than the lower limits of the calculated range are suggestive of spinal canal stenosis. Similarly, the values more than the upper limits of the calculated range are suggestive of intraspinal tumor (Table 4). When the means of the present study were compared with other studies,[7] it was observed that the mean transverse diameter showed an increasing trend from L_1 to L_5 but the mean was more pronounced at L_5 in all studies (Table 5). In the present study, the mean values in the case of males were found to be higher at L_3, L_4, and L_5 than those in other studies, while in females it was comparable with the means of Sotho Negroid females (Table 6).[15]

4.2 *Transverse diameter of vertebral body*

The increasing diameter of vertebral body from L_1 to L_5 in both the groups was probably because of the increase in load bearing from above downward. It was also seen that the diameters of vertebral bodies were larger in males than those in females. The differences between the means of the two were statistically highly significant. The transverse growth of vertebral body is dependent on masculinity to some extent.[16] This fact contributes to larger transverse diameters of vertebral bodies in males, who are more muscular than females. In a study conducted by Devi,[7] it was seen that the mean transverse diameter showed an increasing trend from L_1 to L_5 except at L_4 level (Table 5). When the transverse diameter of vertebral body was compared in between males and females, the values of the present study were slightly lower as compared to those in other studies[15] (Table 6).

4.3 *Canal body ratio*

Theoretically, it was expected that the size of vertebral body should vary proportionately with the build of the individual. In order to find out the relationship between the canal and body size, a comparison was made by finding the ratio between the mean transverse diameter of canal and the mean transverse diameter of vertebral body at various vertebral levels.[17] The results showed that as the size of vertebral body changes, the transverse diameter of canal also varies, maintaining a ratio of 0.6 at each vertebral level in both the sexes. Thus, any deviation of the canal body ratio

Table 6 – Comparison of mean transverse diameter of spinal canal and vertebral body in males and females of present study with those of previous studies.

Dimensions	Level	Authors							
		Present study		Eisenstein 1977 [15] (South African Caucasoid)		Eisenstein 1977 [15] (Zulus)		Eisenstein 1977 [15] (Sotho Negroid)	
		Males (n = 44)	Females (n = 40)	Males (n = 78)	Females (n = 35)	Males (n = 108)	Females (n = 54)	Males (n = 106)	Females (n = 62)
Transverse diameter of spinal canal (mm)	L_1	22.16	19.84	23	22	21	20	21	20
	L_2	22.66	20.16	24	22	22	21	21	20
	L_3	23.66	21.59	23	23	22	21	22	21
	L_4	24.78	23.09	24	23	23	22	23	22
	L_5	27.03	25.47	26	25	26	24	25	24
Transverse diameter of vertebral body (mm)	L_1	36.19	33.34	39	34	39	35	38	34
	L_2	38.09	35.22	40	35	40	37	39	36
	L_3	40.19	37.16	43	37	42	38	41	38
	L_4	42.44	39.69	44	39	44	41	43	40
	L_5	45.44	41.84	46	42	45	43	44	42

Table 7 – Comparison of mean anteroposterior diameter of spinal canal and vertebral body in males and females of present study with those of previous studies.

Dimensions	Level	Authors			
		Present study		Amonoo-Kuofi 1985 [6] (Nigerians)	
		Males (n = 44)	Females (n = 40)	Males (n = 79)	Females (n = 43)
Anteroposterior diameter of spinal canal (mm)	L_1	16.63	15.66	16.60	15.80
	L_2	15.66	15.00	15.80	15.10
	L_3	15.03	14.31	14.90	14.20
	L_4	14.50	13.50	15.60	14.10
	L_5	13.85	12.78	16.00	14.60
Anteroposterior diameter of vertebral body (mm)	L_1	29.50	27.03	29.20	26.10
	L_2	30.35	27.88	30.60	27.60
	L_3	31.09	28.47	32.20	29.10
	L_4	31.75	29.09	34.00	31.10
	L_5	32.28	29.84	34.20	31.30

from its approximate value of 0.6 to one or the other side indicates the possibility of intraspinal tumor.

The calculation of canal body ratio for different segments can also help in specifying whether an individual's measurement on spinal canal is within the normal limits for the respective body size or not, thus helping to identify a stenosis or enlargement of the spinal canal.[18,19] When the canal body ratio values of the present study were compared with those of the previous study done by Devi[7] in South Indian population, it was observed that in the present study, it was constant at all levels approximately 0.6, while in the Devi[7] study, it was also constant at all levels approximately 0.5 (Table 5). Though the values of canal body ratio are different in both the studies, they were constant in that particular study, thus maintaining the relation of spinal canal with that of vertebral body at that particular vertebral level.

4.4 *Anteroposterior diameter of spinal canal*

The first lumbar vertebra coincides with the region of functional transition between the relatively immobile thoracic spine and the mobile lumbar spine. It also lodges the lower end of the spinal cord and the conus medullaris. Therefore, the larger size of the canal at this level ensures protection of the contents during complex movements at this transitional region apart from accommodating the larger size of its contents. The gradual decrease in the spinal canal explains the transition of spinal canal from lumbar type to sacral type.[17–20] Considering the calculated range, values less than the lower limits of the calculated range are suggestive of spinal canal stenosis. Similarly, the values more than the upper limits of the calculated range are suggestive of intraspinal tumor (Table 4).

As per Table 7, the mean anteroposterior diameter of spinal canal in the present study is comparable at all levels except at L_4 and L_5, where Amonoo-Kuofi[17] reported a larger diameter of spinal canal.

4.5 *Anteroposterior diameter of vertebral body*

The mean anteroposterior diameter of vertebral body progressively increased from L_1 to L_5 in both males and females. It was also evident that the difference between the means of both sexes was statistically highly significant. Table 7 shows that the mean values increasing from higher to lower levels (L_1 to L_5) but the values are slightly greater in the case of Nigerians[17] than in the present study done in Western Maharashtra population which could be probably due to racial and ethnic differences between the two.

4.6 *Spinal index of Jones*

The spinal index of Jones increased from L_1 to L_5 in both the sexes. The mean values were slightly lower in females as compared to those in males and the difference was found to be statistically significant at all levels.

The canal body ratio described earlier also gives information about the proportion of body and corresponding spinal canal but in that case, only transverse dimensions are taken into consideration, while this index directly gives information about the proportion of transverse diameter and the anteroposterior diameters of body and corresponding spinal canal.

Using the calculated range, it is observed that the values more than the upper limits of the calculated range indicate the possibility of spinal canal stenosis. Similarly, the values less than the lower limits of the calculated range are suggestive of intraspinal tumor (Table 4).

Thus, the comparison of results of the present study with those of previous studies shows that there are marked differences between the mean values reported for different geographical areas. The reasons for these differences are not clear, but the interplay of racial, ethnic, and environmental factors cannot be ruled out.

Variation in skeletal morphology in the people of different zones of India is common as there is existence of a racial mixture in this part of the world. It seems, therefore, that to make a definite diagnosis of lumbar vertebral pathologies based on the measurements of different lumbar vertebral dimensions, there must be baseline figures that are applicable not only to the sex group but also to the geographical location under consideration. These figures could be of forensic importance because of the observed racial, ethnic, and regional variations.

5. Conclusion

An osteological study of transverse diameter and anteroposterior diameter of lumbar spinal canal and vertebral body was carried out as well as various indices based on such measurements were calculated. It was found that these parameters showed statistically significant differences in their mean values for males and females indicating sexual dimorphism, thus necessitating separate normal ranges for male and female. However, sometimes there is considerable overlapping of the ranges in male and female. This probably reflects the wide variations of body sizes among male and female subjects.

Comparison with other groups also showed ethnic variation. Thus, with this study we have tried to present a set of baseline measurements of lumbar vertebrae in Western Maharashtra subjects. Furthermore, a careful study of these

Fig. 1 – The measurement of transverse diameter of spinal canal.

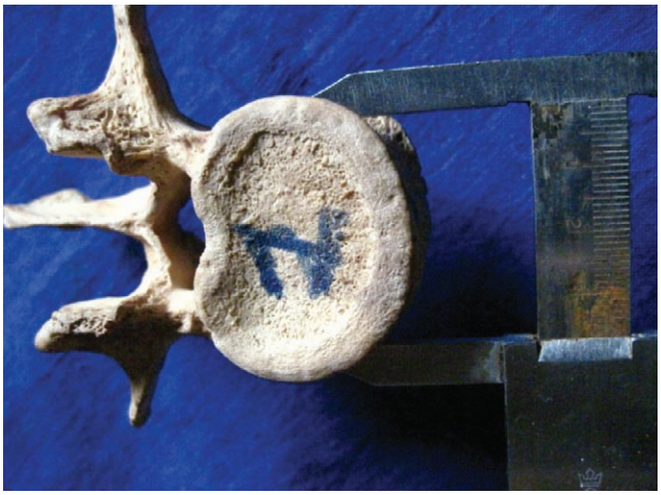

Fig. 2 – The measurement of transverse diameter of vertebral body.

Fig. 3 – The measurement of anteroposterior diameter of spinal canal.

Fig. 4 – The measurement of anteroposterior diameter of vertebral body.

parameters can be useful in detection of clinical conditions such as spinal stenosis and intraspinal tumor. However, continuance of such studies in a defined geographical area over a period of time is suggested as it will be helpful in observing the changing trends in metric measurements if any.

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